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Land Classification Used to Select Abandoned Hazardous Waste Study Sites

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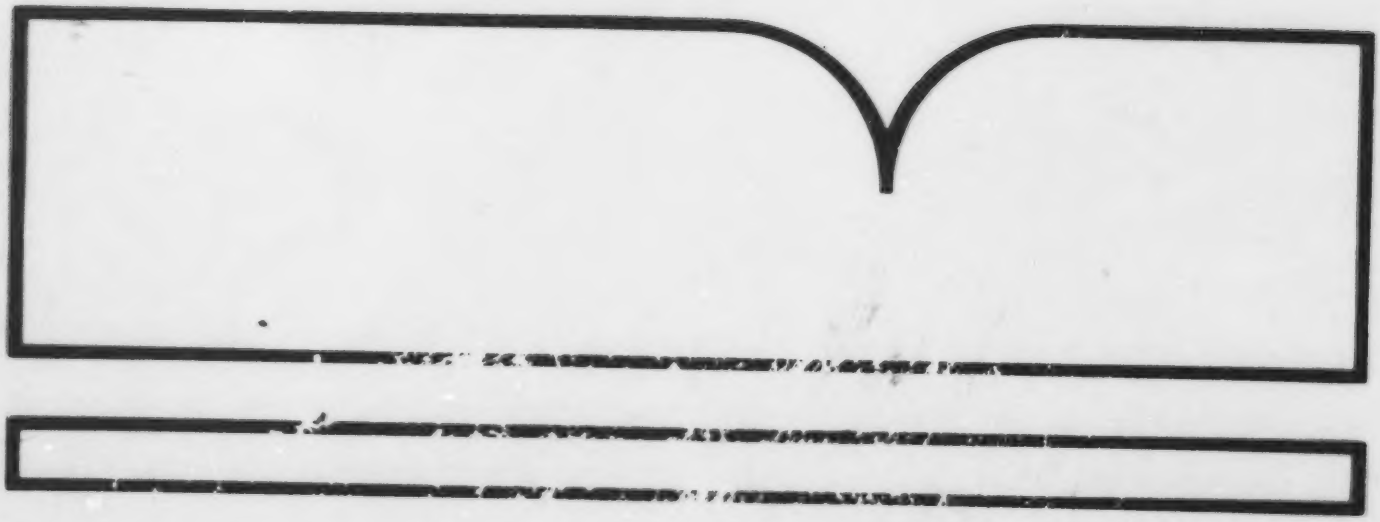

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16. ABSTRACT

The biological effects of hazardous substances in the environment are influenced by climate, physiography, and biota. These factors interact to determine the transport and fate of chemicals, but are difficult to model accurately except for small areas with a large data base. The requirement for large data base may be reduced locally if the regional influences of these factors were predetermined from existing data. Knowledge of the regional factors would also relax the restriction to considering only small areas. This paper advocates consideration of regional characteristics of the environment in the early stages of waste management strategy development. It presents as an example a procedure for selecting study sites from candidate-abandoned hazardous waste dumpsites in the southeastern United States. It uses small-scale maps of low resolution from the National Atlas to delineate the boundaries and to determine the environmental characteristics that prevail over units of land within the region. A computer map-overlay and graphic approach is used to facilitate the grouping of land types. Abandoned hazardous waste dumpsites found within land types that best represent the region are surveyed for selecting a study site. It is expected that environmental impact data obtained from a representative site would be useful for predicting impact potentials in similar remotely located areas within the same general region.

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FORUM

Land Classification Used to Select Abandoned Hazardous Waste Study Sites

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ABSTRACT / The biological effects of hazardous substances in the environment are influenced by climate, physiography, and biota. These factors interact to determine the transport and fate of chemicals, but are difficult to model accurately except for small areas with a large data base. The requirement for a large data base may be reduced locally if the regional influences of these factors were predetermined from existing data. Knowledge of the regional factors would also relax the restriction to considering only small areas. This paper advocates consideration of regional characteristics of the environment in the early stages of waste management strategy development. It presents as an example a procedure for selecting study sites from candidate-abandoned hazardous waste dumpsites in the southeastern United States. It uses small-scale maps of low resolution from the National Atlas to delineate the boundaries and to determine the environmental characteristics that prevail over units of land within the region. A computer map-overlay and graphic approach is used to facilitate the grouping of land types. Abandoned hazardous waste dumpsites found within land types that best represent the region are surveyed for selecting a study site. It is expected that environmental impact data obtained from a representative site would be useful for predicting impact potentials in similar remotely located areas within the same general region.

Abandoned hazardous waste sites often release toxic chemicals to the environment through leaching, erosion, runoff, volatilization, and fire. Uptake by plants and animals further contributes to the dispersion of toxic chemicals from a site. The rate of release of chemicals depends on the method of containment, climate, land form, surficial geology, vegetation, soil type, and land use. The environmental impact of toxic chemicals also is influenced by all these factors. Currently, there is inadequate understanding of the mechanisms involved and thus no way to accurately model these releases or to determine their impact (US House of Representatives 1979). But there is a need to assess the extent of the problem at a given site, suggest remedial action when necessary, and determine the effectiveness of actions taken to restore the environment.

To assess the direct impact of complex waste within soil and water samples from actual waste sites, simple laboratory biological screening tests can be performed on selected organisms such as soil microbes, algae, daphnia, fathead minnows, earthworms, and crop seeds (Waters and Little 1980, Schaeffer and others 1982, Samoiloff and others 1983, Porcella 1983). To determine the applicability of these tests over a wide range of climatic conditions, waste types, and management practices, they need to be conducted with samples from sites that are located within regions representative of diverse geographic conditions in the United States. Field studies must also be conducted at a few study sites in a region to relate the extent of ecological damage to the laboratory tests. A positive correlation between laboratory and field results will be used to determine whether it is possible to assess damages at other sites in the region using laboratory studies alone. But to extend this kind of information from one site to another, it is necessary for the sites to be within ecologically similar types of lands. Ecological similarity is more simply identified at a low level of resolution on a regional basis. This level of accuracy may be insufficient, because natural variabilities in a land become important on a more local level. Thus, in practice, additional data may be needed to ensure that a study site and its immediate surroundings are adequately representative of a larger area in a region.

KEY WORDS: Ecosystem classification; Research sites; Hazardous waste; Map integration; Computer graphic

Abandoned hazardous waste sites are not necessarily numerous in dominant land types within a region. However, a focus on dominant land types is likely to capture more of the central characteristics of the region, effect a greater utility of the data to broad areas, and provide a preliminary rationale for the long-range management of hazardous waste on a more regional basis.

A computerized map-overlaying procedure was developed for selecting sites for field/laboratory studies in the southeastern United States. The region was classified in a hierarchy of land types ranging from the least typical to the most typical based on regional patterns in surficial geology, soils, land surface forms, and potential natural vegetation. Then, candidate study sites were selected from abandoned hazardous waste dumps found within the most typical land types. The rationale is that results from studies conducted at these sites would have greater potential for representing average conditions in the region than would studies of sites in relatively uncommon land types.

This paper describes the site selection procedure only. The test of whether or not sites selected in this manner do indeed satisfy the objectives of the stated bioassay test program will be conducted in a separate comprehensive ecological study of the sites in the Southeast.

Figure 1. Ecoregions of United States adapted from Bailey (1976).

Approach

Map-overlay procedures have been used to accomplish diverse objectives. Some examples include urban planning (McHarg 1969), relating the ecology of aquatic to terrestrial systems (Omernik and others 1981), determining environmental suitability for facility siting (Hepner 1981), and selecting research sites representative of agronomic conditions for crop production (Ford and Nielsen 1982). Theoretical concepts on the potential use of classification for environmental management can be found in Warren (1979). Row and Sheard (1981) approach land classification based on ecological theories and use it as a precursor to a statistical analysis. Cowardin and others (1979) developed an extensive classification of wetlands and deepwaters for the United States. The uses of classification in the Natural Heritage inventory is given by Radford and others (1981).

The emphasis in this report is to use existing small-scale maps of low resolution for determining environmental characteristics that prevail over a region. Generalized or regionalized maps of this type are particularly appropriate for this study. These maps bring out only those environmental characteristics that, on the average, hold true over a whole region. Details that do not pertain to generalized understanding of a large area are omitted. The maps are used in an overlay procedure to classify land units in a hierarchy of types ranging from the least to the most typical of the regional characteristics.

Available regionalized maps depicting physiographic land divisions in the conterminous United States (Fenneman 1946), land surface form (Hammond 1964, USDI Geological Survey 1970, Bailey and Cushwa 1982), potential natural vegetation (Kuchler 1966 and 1964), soils (USDA Soil Conservation Service 1967), land resource (Austin 1972), surficial geology (Hunt 1979), hydrology (Bailey and Cushwa 1982, Anderson 1967), and climate (USDI Geological Survey 1970) can be

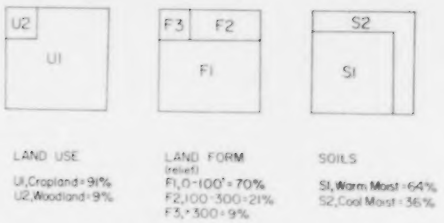

Figure 2. A hypothetical example showing single dominant characteristics of an ecoregion by areas in land use, land form, and soil.

used to identify interrelationships and distributions of combined geologic, biologic, and climatic influences on land. These maps are presented at a scale of 1 mm = 7.5 km and constitute the most compatible data base available at that level of resolution.

An area may be characterized by one map unit depicting land form, two map units depicting vegetation, and as many as six map units depicting soils. This holds true even when regionalized maps are drawn to the same scale. There exists no general rule to guide the integration of several maps of dissimilar classifications. However, since various characteristics of the environment are interrelated, in many places a spatial correlation of several related characteristics in the region is often possible. This is a crucial point of our approach.

Bailey's (1976, 1980, and 1982) division-level ecoregion (Figure 1) is used here as a convenient starting point for a regional approach to the problem. No subdivisions below this level from the Bailey classification are used in this paper. Instead, regionalized thematic maps are used to further subdivide a division directly into a hierarchy of areas of land types ranging from the most typical to the least typical. The most prevailing areas are likely to represent the division characteristics as a whole. The less common land types are likely not to reflect the division characteristics, but show influences of one or more of the neighboring regions. This approach may equally as well be applied to lower subdivisions of Bailey classes. The division level appears to be more suitable for the present objectives.

The analysis of the data for identifying various land types can best be presented by means of a simple hypothetical example. Let us assume that a region covers a square area and that the area may be described using information obtained from a land use map, land form map, and the soils map as shown in Figure 2. In this Figure, the land areas with characteristics from various maps are designated in symbols with numbers as shown. Thus, the land use is predominantly cropland (that is, U1 = 91% of the total area), the land form is generally low relief (F1 = 70%), and the soil is mostly warm and moist (S1 =

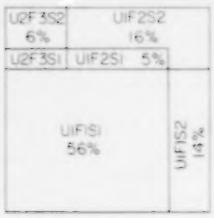

Figure 3. A hypothetical example showing combined characteristics in land use, land form, and soils in an ecoregion. U1F1S1 = 56% is the most typical and U2F3S1 = 3% is the least typical of the ecoregion.

64%). From successive overlays of land use, land form, and soils maps, we find that the area sharing the dominant of the three characteristics typifies more than half of the region (U1F1S1 = 56%, Figure 3). These are the low-relief, warm, and moist soil croplands. In contrast, highly dissected woodlands with cool moist soils are the least typical, comprising a very small fraction (U2F3S2 = 3%) of the total region. Data from a site located within the boundaries of U1F1S1 are more likely to integrate the effects of the most common regional characteristics than would data from U2F3S2. Therefore, the data from U1F1S1 would be more representative and would have potential transferability to a large portion of the region. In contrast, data from a U2F3S2 site are more likely to represent anomalies than dominant characteristics of the region. The potential use of the latter data in environmental management is for identifying the relative variabilities in the region and for setting limiting conditions to the overall regional management approach.

Analysis of a Case Study

Maps of land form, surficial geology, potential natural vegetation, and soils corresponding to Bailey division 2300 (Figure 1) were manually digitized with a grid-sized resolution of 1 m^2. Since 1 mm on the map represents 7.5 km of land, a matrix of 228 rows by 250 columns of 1-mm^2 cells was required to cover the region. The digitized information was condensed by encoding repeated map features appearing in each row by the column number of the last cell. In this manner, a string of repeated similar map units was represented only by one position number in a row and by the code of its map unit. All cells outside the ecoregion boundary were encoded as -1. The condensed data were stored in a computer and decoded when needed to reconstruct a computer map image suitable for plotting. The problems of digitization, editing, computation, and graphics are detailed in a separate paper by Shirazi et al. (1984).

The analysis began by using the computer to determine the percentage of total area in the ecoregion covered by individual components of land form, vegetation, geology, and soils (Table 1). Irregular and flat plains dominate the area in equal proportions (totaling 79.5%), oak–hickory–pine forests are the dominant vegetative life forms (53%), Udult soils cover 54.2% of the area, and loam deposits cover 36.1% of the area.

Next, the computer was used to search for relatively large and contiguous land types covered by dominant, but interrelated, characteristics in land form, vegetation, soils, and geology. Even with advanced computers, this can be a very difficult task unless supported by a rationale to reduce the number of variables entering the computation. The number of variables in Table 1 may be reduced, but not eliminated from consideration, by combining similar components into a single map group. Many attempts were made to accomplish this task, but the following rationale appears to be the most effective.

The region is influenced predominantly by the marine environment in the south and the east, by the mountains in the north, and by the alluvial plains of the lower Mississippi in the west. The characteristics in Table 1 individually represent these features. A convenient representation was obtained by placing an item in group 1 if it reflected a coastal/alluvial floodplain environment; the remainder were assigned to group 2. Group assignments were done manually. In the majority of cases, like objects from different maps were easily recognized from map unit names. For the more difficult items, individual maps were consulted to identify related features based on the approximate spatial relationships of the items.

Accordingly, the southeastern coastal and inland floodplains are characterized by floodplain forests, grass and grassland forests (V1); warm and wet soils (S1); organic, shore, eolian, lake, and alluvial deposits (G1); and flat, smooth, and irregular plains (F1). On the other hand, the upland piedmonts are characterized by oak–hickory–pine forests (V2); warm and moist soils (S2); saprolitic and colluvium deposits (G2); and hills and mountains (F2). This means that spatial correlations represented by V1S1G1F1 and V2S2G2F2 each would delineate a distinct class of land within the ecoregion, one coinciding with alluvial/coastal plains and the other with the mountains. Whether or not each is the dominant or most representative, or there may exist other dominant classes sharing some characteristics from each, must be explored by an exhaustive search of the 16 combinations obtained from binary-grouped features within four maps. A similar delineation that brings out related ecological attributes of various land types is not possible from the use of a single thematic map.

Figure 4 identifies the spatial distribution of land types together with the percent of the total ecoregion area each occupies. For example, land types V1S1F1G1 occupying the coastal and inland floodplains and V2S2F2G2 occupying the

Table 1. Breakdown by major classes and percent area covered by vegetation, soils, geology, and land form within Bailey ecoregion 2300 (humid subtropical division).

VEGETATION *Class*	*Life form*	% *Area*	*Map group*
C and E grass forest	Blackbelt	1.38	V2
C and E grass forest	Live oak–sea oats, everglades	1.62	V1
C and E grassland	Cordgrass, bluestem savanna	4.82	V1
E broadleaf	Oak–hickory forest	1.86	V2
E broadleaf	Appalachian oak forest	1.02	V2
E broadleaf and needlf	Oak–hickory–pine forest	50.34	V2
E broadleaf and needlf	Southern mixed forest	22.67	V2
E broadleaf and needlf	Southern floodplain forest	14.79	V1
E broadleaf and needlf	Pocosin and sandpine scrub	1.50	V1

SOILS *Temp.*	*Moisture*	*Order*	*Suborder*	% *Area*	*Map group*
Cool	Moist	Spodosols	Orthods	0.31	S2
Warm	Dry	Alfisols	Ustalfs	0.50	S2
Warm	Moist	Alfisols	Udalfs	4.68	S2
Warm	Moist	Entisols	Psamments	4.23	S2
Warm	Moist	Inceptisols	Ochrepts	1.51	S2
Warm	Moist	Mollisols	Udolls	1.01	S2
Warm	Moist	Ultisols	Udults	54.21	S2
Warm	Moist	Vertisols	Uderts	1.01	S2
Warm	Wet	Alfisols	Aqualfs	2.27	S1
Warm	Wet	Entisols	Aquents	0.62	S1
Warm	Wet	Histisols	Saprists	1.90	S1
Warm	Wet	Inceptisols	Aquepts	10.38	S1
Warm	Wet	Mollisols	Aquolls	1.11	S1
Warm	Wet	Spodosols	Aquods	6.22	S1
Warm	Wet	Ultisols	Aquults	10.06	S1

SURFICIAL GEOLOGY *Class*	*Type*	% *Area*	*Map group*
Saprolitic	Kaolin, with mica, quartz and red clay	14.30	G2
Saprolitic	Phosphatic and shale clay, triasic	2.67	G2
Saprolitic	Loam	36.09	G2
Saprolitic	Sand from shale, silt	1.84	G2
Saprolitic	Gravel	0.76	G2
Eolian deposits	Loess, sand sheets	3.95	G1
Organic deposits	Coastal sand and peat	10.09	G1
Lake deposits	Lake	0.26	G1
Stream deposits	Floodplain/alluvium gravel	17.68	G1
Colluvium	Sand and stone	5.87	G2
Miscellaneous	Basalt	0.12	G2
Shore deposits	Backshore, sea island	6.38	G1

LAND FORM *Class*	*Form*	% *Area*	*Map group*
Plains	Flat plains	39.70	F1
Plains	Smooth plains	4.86	F1
Plains	Irregular plains	39.81	F1
Tablelands	Considerable relief	1.58	F2
Plains, hills, or mts.	With high hills and mts.	4.02	F2
Open, hills, or mts.	High hills and low mts.	10.03	F2

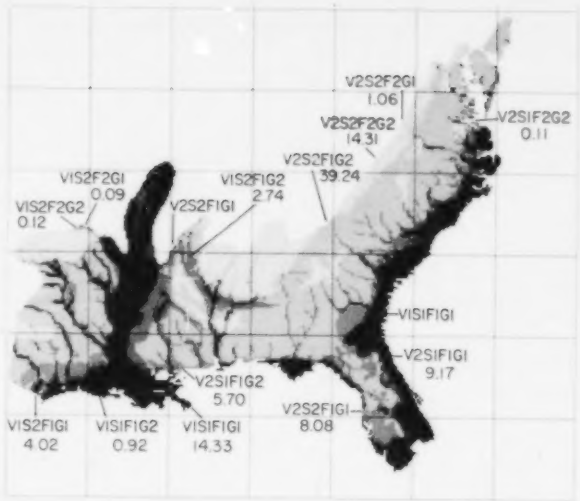

Figure 4. Percent areas and distribution of land types in Division 2300 based on a binary grouping of vegetation (*V*), soils (*S*), land forms (*F*), and geology (*G*) in combinations of like characteristics representing coastal/inland environments (*1*) and others (*2*).

upland piedmonts are 14.3% each. A major transitional land type connecting the two is 39.2%. This land type V2S2F1G2 dominates the coastal piedmonts. Numerous smaller transitional land types are shown in the map. They locally link neighboring lands to produce a continuous and gradual change of spatial ecological characteristics. For example, V2S1F1G1 along the coastal plains is formed by the intrusion of oak–hickory–pine forests into predominantly coastal floodplains and V2S2F1G1, along the inland floodplains, is formed by the intrusion of mixed forests and moist warm soils into lowland alluvial systems.

This analysis makes it possible to delineate boundaries of land types and identifies each with prevailing components of vegetation, land form, geology, and soils. Land types having largest areas are more likely to represent the average or central environmental characteristics of the region as a whole.

Depending upon available resources and problem objectives, the following alternatives apply to the use of the results. A list of existing abandoned hazardous waste sites in the region must be reviewed and, among those found within land type V2S2F1G2 in the coastal piedmonts, one or more should be considered for a study site to capture the typical characteristic of the region. These lands are dominated by oak–hickory–pine forests in the north and east, southern mixed forests in the south, Udult soils, flat and irregular plains, and loam deposits. In considering additional sites within land types in floodplains (V1S1F1G1) or upland piedmonts (V2S2F2G2), a wider

range of conditions in the ecoregion is likely to be represented. In selecting sites within progressively less representative areas such as upland or transitional areas, there will be more deviation from the typical features of the ecoregion, thus providing less and less extrapolation potential for the data generated.

Finally, an actual abandoned site selection must meet requirements other than representativeness in the above sense. Among these are easy access, safe working environment, documented history, adequate data base, representative waste type, and representative waste management. These factors are not covered in this paper. Three abandoned hazardous waste sites were finally selected from EPA's 114 top priority sites (USEPA 1981). The three sites were within the boundaries of coastal piedmont plains (V2S2F1G2). The landscapes surrounding the sites were inspected at the ground level and from aerial photographs to ensure general conformity with mapped data. One site is located near Kynesville, Florida, a second in Gainesville, Florida, and a third in Columbia, South Carolina. Ecological studies are planned for all sites. One will be studied comprehensively; the other two will be used to examine the potential for data extrapolation.

Conclusion

The outcome of classification would be affected by the choice of a grouping that is used to search for similar land types. The above rationale appears to produce reasonable results and might be useful for other applications. The field test planned as a continuing part of this project would better determine the adequacy of the rationale to satisfy the objectives of the problem at hand.

Environmental management can greatly benefit from land classifications based on regionalized data representing important ecological characteristics. Classification could help identify lands of similar attributes and facilitate transfer of data from a site for which there are adequate data to other sites of the same type that lack similar data. For the problem at hand, classification enhances the ability to predict potential environmental impacts of hazardous wastes.

The classification of land masses into a number of homogeneous subclasses based on regional characteristics promotes problem examination from the "top," focusing first on the major, dominant characteristics at an early stage of analysis. The procedure is not limited to a low level of spatial resolution. However, the data requirements for high resolution covering small areas are extensive and the data frequently are unavailable.

No matter how homogeneous a land type may appear at a low level of resolution, there are always variations at a higher level. These may occur because of spatial influences of the neighboring areas with slightly different characteristics. Hence, as the focus shifts from a small area to a whole region, the interpretation of the utility of the data must also shift from a direct application of the details to a general understanding of patterns.

There is a wide gap between our desire to generalize results over broad regions and our ability to assess very small areas based on these generalizations. The reasons are lack of an extensive data base and inadequate understanding of interaction among environmental characteristics. Extensive data on many small areas could be better integrated if we had some knowledge of the regional characteristics, for example, as may be obtained by the above procedure. Likewise, with this knowledge of the regional characteristics, we can attempt to analyze small areas within a region and expect that we are generally successful in capturing major features within each land type. It takes both approaches to reduce this gap.

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